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PLANT PROTECTION OVERSEAS REVIEW

JUNE

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PLANT PROTECTION LTD

PLANT PROTECTION OVERSEAS REVIEW

A PERIODICAL SURVEY OF NEW DEVELOPMENTS IN THE CONTROL OF PESTS, DISEASES AND WEEDS

PUBLISHED BY THE EXPORT DEPARTMENT

PLANT PROTECTION LTD

BOLTON HOUSE, 61 CURZON STREET, LONDON, W.1

THE SECOND INTERNATIONAL CONGRESS OF CROP PROTECTION

This important Conference is being held in London from the 21st to the 28th July, 1949. Readers of the Overseas Review will be interested to learn that Plant Protection Ltd. is taking the opportunity given by this international occasion to welcome the delegates from all parts of the world at their research station at Fernhurst in Sussex. A whole day—Tuesday 26th July—will be spent in touring the estate and viewing the special exhibits staged for their benefit.

Travelling by coach from London, the delegates will be able to gain an excellent impression of agricultural conditions in Southern England as they drive through some of the finest examples of the English countryside. At Fernhurst, in addition to inspecting the farms, orchards, glasshouses and market garden, our visitors will have an opportunity of seeing a special exhibit entitled " The Evolution of a Plant Protection Product ". This will depict the work of the I.C.I. manufacturing divisions as well as the I.C.I. agricultural research stations and the way in which their activities are linked with the field trials and demonstrations organized under the aegis of Plant Protection Ltd.

An exhibition is also being staged by at least twenty-five British agricultural machinery manufacturers who will give practical demonstrations of all types of applicators of crop protection products.

These and other items will comprise a full and varied day's programme for the delegates whom we greatly look forward to entertaining on this occasion.

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'PLANT PROTECTION' CONFERENCES

IN October and November, 1948, Plant Protection Ltd. inaugurated two Conferences the one in Montevideo, the other in San Salvador C. A. with the primary object of enabling our representatives in South and Central America to meet each other and discuss problems of common interest with the mission of specialists sent by Plant Protection Ltd. from England. The full list of delegates to each of these Conferences is given below.

The papers submitted to these Conferences and the discussions which followed were naturally concerned with problems peculiar to those territories but nevertheless some of the papers were of a more fundamental character and we believe will be found of great interest to many others outside the western hemisphere. It is for this reason that we have decided to devote this number of " Plant Protection Overseas Review " to the publication of selected papers from both Conferences.

We have selected the papers purely on the basis of their general interest value and in several cases we have, for reasons of space as well as suitability, pruned the contents of the articles considerably without, we hope, destroying their intrinsic value. A number of the papers were written in Spanish and are, therefore, reproduced here in translation.

These two Conferences, the first to be held by Plant Protection Ltd. outside the United Kingdom, were judged by all those who attended them to be extremely successful and fully justified the time and trouble taken by those responsible for organization. Plant Protection Ltd. wishes to take this additional opportunity of thanking Mr. K. Knudsholt of Industrias Quimicas Uruguayas " Duperial " S.A., and Mr. S. M. Stadler of S. M. Stadler & Co., for their contributions to the success of the Conferences at Montevideo and San Salvador respectively.

LIST OF DELEGATES TO SOUTH AND CENTRAL AMERICAN CONFERENCES

At Montevideo : 8th to 15th October, 1948

Delegate	*Representing*
Mr. K. Knudsholt	" Duperial " Uruguay
„ C. F. Wilson	
„ W. Barbot	
„ A. Kelly	
„ P. C. Lake	
Mr. S. B. Feeney	" Duperial " Argentina
„ M. H. Fernandez Oro	
„ D. N. Graham Yooll	
„ D. Fischetti	
„ A. C. Della Costa	
Dr. C. M. McLeod	
Mr. I. R. Burbridge	" Duperial " Brazil
Dr. E. S. Freire	
Mr. Karner Hagelund	
Mr. T. D. Walker	I.C.I., Chile
„ E. Zomosa	
Mr. C. Stenning	I.C.I., Peru
Mr. G. L. Windred	I.C.I., General Chemicals Division
Mr. Julio de Soto	Director General del Servicio de Lucha Contra la Langosta
Mr. O. B. Lean	Plant Protection Limited
„ B. P. Peters	
„ F. G. Ordish	

At San Salvador : 22nd to 27th November, 1948

Delegate	*Representing*
Mr. S. M. Stadler	S. M. Stadler & Co. (El Salvador)
Mr. F. de Sola „ H. Cardona „ R. Quinonez „ A. Pacas „ G. Benavides „ C. Altschul	De Sola & Co. (El Salvador)
Mr. F. Barnoya Dr. A. Porras	De Sola & Co. (Guatemala)
Dr. A. Figueroa	Cooper, McDougall & Robertson Ltd. (Colombia)
Mr. J. Michell	I.C.I. (Jamaica, British West Indies)
Mr. T. E. K. Potter	Geddes Grant Ltd. (Trinidad, British West Indies)
Mr. A. A. Hunter	James Brodie & Co. (British Honduras)
Mr. R. G. Peralta	Compania de Comisiones Inter-Americana S.A. (Honduras)
Mr. A. Sevilla	P. J. Frawley (Nicaragua)
Mr. E. Sasso	International Agencies (Costa Rica)
Mr. F. Escoffery Jr.	Agencies Escoffery, S.A. (Rep de Panama)
Mr. C. Fernandez Coto	Zaldo & Martinez (Cuba)
Dr. R. C. Woodward Mr. F. G. Ordish Mr. B. P. Peters	Plant Protection Ltd.

CONTROL OF COTTON INSECTS IN THE STATE OF SÃO PAULO (BRAZIL)

By Dr. E. S. FREIRE

(*Abridged version*)

THE State of São Paulo is the most important in Brazil for cotton production and more than half of the total Brazilian area under cotton (2—2,500,000 hectares) is grown in this State alone.

Owing to the preference for coffee, cotton growing in São Paulo was formerly limited to a relatively small area. However, overproduction of coffee and the consequent decrease in its price created an extraordinary interest in cotton, so that the cultivated area, not exceeding 20,000 ha. in 1929-30, jumped to almost 500,000 ha. in 1934-35, to 1,200,000 ha. in 1939-40, and to over 1,600,000 ha. in 1944-45. Thereafter it began to decrease and in 1947-48 no more than 800,000 ha. were under cotton

Between 1930 and 1940 the average production of the State was estimated at 700—800 kg./ha. of seed cotton. In recent years, however, the yield gradually decreased, dropping to only 450 kg./ha. in 1946-47. This was the principal cause of the reduction in the cultivated area. As to the reduction in average yield, it is to some extent ascribed to erosion and lack of judicious fertilization and crop rotation, as well as weather conditions in the last 3 years, but principally to the damage caused by insects, especially by the recently increased infestation of flea hoppers. In fact, it is estimated that some 75% of cotton in São Paulo is lost through insect damage.

INSECTS OF GREATEST IMPORTANCE

Aphis gossypii Glover. In São Paulo, breeding continues in other plants, even during winter, but it multiplies at an extraordinary rate in the spring, when it attacks the young cotton plants.

Gasterocercodes brasiliensis Hambl. The adult of this beetle enters cotton fields from surrounding vegetation, when the cotton plant is about 10 cm. in height. It feeds on the plant, though causing little damage; however, it nibbles the stem near soil level and lays eggs in the cavity. The larvæ enter the base of the stem and/or the higher part of the root. When bored, the young plants generally die; the grown plants usually resist and can even produce a few bolls.

Horcius nobilellus Berg. and at least 10 other species of the same family, including *Horcius spp.*, *Colocoris stigmosus* Berg. *Lygus spp.*, *Psallus spp.*, *Garganus gracilentus* Stal. and *Creontiades rubrinervis* (Stal). All these species have similar habits and produce similar damage to the cotton plant. Both the adults and nymphs feed on the juices of the tender parts of the cotton plant, specially the terminal buds and small "squares," causing excessive shedding of squares, flowers and young bolls. The infested plant grows taller, with fewer large branches than normal plants. In São Paulo the infestation of the cotton fields by these insects usually starts in December, but in mid-January the population is already appreciable and, if not controlled at that time, it becomes so abundant in February and March, that from the squares, flowers and young bolls formed during these months, only a few remain on the plant and produce normal mature bolls. A loss of some 40% of the cotton production in São Paulo is ascribed to these insects.

Platyedra gossypiella Saunders. The pink boll worm is well established in Brazil. In view of the control measures adopted in São Paulo, the infestation is not usually important at the beginning of the blooming period of the cotton plant, but the population grows quickly and, apart from causing appreciable shedding of flowers and small bolls, in some seasons the final part of the harvest is almost wholly constituted of injured bolls.

Alabama argillacea Hubn. The well known leaf worm does not survive the winter in São Paulo. Although its activity and spread vary greatly from year to year, new infestations generally start in December, but it is usually between January and March that this insect causes the most damage in São Paulo.

MINOR PESTS

The cotton stainer, red spider, boll worm, wireworms, cutworms etc., also damage the cotton crop in São Paulo, but the losses they cause are considered of minor importance compared with those arising from the above-mentioned insects.

USUAL CONTROL METHODS

In general, only the leaf worm has been chemically controlled with lead arsenate. In recent years a few farmers began spraying with nicotine against aphids. Before being delivered to the farmers, all cotton seed is fumigated by the Government with methyl bromide; this contributes to a reduction in the initial infestation of pink boll worm. Experiments made by the Biological Institute, São Paulo, showed that it is possible to control *Gasterocercodes brasiliensis* with sprays or dusts of calcium arsenate, but this is not yet widely used. As to the flea hoppers, they have only recently been considered as serious pests in São Paulo.

RECENT EXPERIMENTS OF THE BIOLOGICAL INSTITUTE

During the past cotton season several large scale trials were made by the Biological Institute in different parts of the State of São Paulo for the control of the major cotton insects. The results of 5—6 experiments with replicated plots and those of 1 or 2 demonstrations in large areas, without replications but carefully controlled, have shown that, using modern insecticides like BHC, DDT and others, it is economically possible to combat all the important cotton insects of São Paulo, for their control caused an increase of production averaging 680 kg./ha. of seed cotton, the value of which by far exceeds the cost of the treatment.

A full report of these experiments has not yet been published, but the principal experimenter—H. F. G. Sauer—has published his interim recommendations in a technical paper ; he also gave us further verbal information on the subject. We have tried to place current recommendations in a short and clear form in the attached table.

Sauer's main idea, when planning last season's trials, was to verify whether it would be possible to control, under local conditions, all our major cotton insects. As it was not practicable to compare at the same time various insecticides in increasing concentrations and dosages, those most likely to be suitable for each case were chosen. In the concentrations and dosages mentioned in the table—which were those used in the trials—all the products have proved efficient for the cases recommended. There are indications that, using certain insecticides, almost complete control can be obtained with much lower concentrations or dosages. However, the layout of the experiments does not permit an estimate of the degree of such reduction. This is also the reason why it is not yet possible to determine the economically most advantageous insecticide in each case.

Sprays and dusts were not compared in the individual experiments. Although the former method needs a much smaller quantity of insecticide, our farmers are mainly equipped with sprayers. Sauer prefers the latter, principally because dusting is quicker and does not depend on the operator's skill.

For dusting he recommends a powder passing 95% through a 325 mesh. Talc or sulphur are indicated as diluents. Beside being a good filler for dusts, sulphur has the advantage of preventing an increase of the red spider population. Observations in the next few seasons will show whether it is possible to dispense with the use of sulphur and change to talc as a cheaper vehicle.

In the present recommendations there are many gaps, which will be filled in after further experiments have been made. It will also be noticed that no uniform relationship exists between the concentrations

For the control of:	Aphids	Gastero-cercodes	Pink boll worm	Flea hoppers	Leaf worm	All the insects
DUSTS containing:						
% gamma BHC	1.5	3	—	—	—	—
or % gamma plus % S.	—	—	—	3+40	3+40	—
or % DDT plus % S.	—	—	10+75	5+75	—	—
or % DDT+ % gamma+ % S. ...	(5+3+40)	(5+3+40)	(5+3+40)	(5+3+40)	(5+3+40)	(5+3+40)
or % E.605 (Rhodiatox)	0.25	0.50	—	0.25	0.25	?
or % Toxaphene	—	20	—	20	20	20 (?)
or % Calcium Arsenate	—	100	—	—	100	—
—Kilos/hectare of dust	10	10	12—16	12—16	12—16	10—16
						Flea h. + pink b.w. + leaf w.
SPRAYS containing:						
% gamma BHC	0.02	0.03	—	0.02	0.02—0.03	—
or DDT	—	—	?	0.25	—	—
or DDT plus % gamma	—	—	?	—	—	0.15+0.03
or % E.605 (Rhodiatox)	0.00625	?	—	0.01	0.00625	?
or % Calcium Arsenate	—	0.80	—	—	—	—
or % Lead Arsenate	—	—	—	—	0.5	—
—Litres/hectare of spray	100	100—120	—	250—320	200—250	250—320
Approx. time for treatments ...	Nov./Dec.	Nov./Dec.	Jan./Feb.	Jan./Feb.	Dec./Mar.	Jan./Feb.
Approx. interval between treatments (days)	?	?	?	7—10	?	(7—10)
Approx. number of applications ...	1—2	2—4	?	2—4	2—4	(2—4)

and dosages indicated for dusts and sprays, as for instance in the case of the DDT plus BHC mixture. The explanation is that, as sprays versus dusts were not compared in the individual trials, the concentrations and dosages for each method were chosen independently, and only the concentrations in fact tried out were mentioned in the recommendations.

Recognising that recommendations are too complicated for most of our farmers, it seems that Sauer's tendency is to indicate principally a " catch-all " mixture—like that containing 5% DDT plus 3% gamma BHC plus 40% S. It would be better from an economic point of view to use this mixture only in the second period of the cotton season, when the appearance of the flea hopper and pink boll worm is almost certain and that of the leaf worm very probable, while in the first period only the products particularly indicated against *Gasterocercodes* and aphids would be employed, if necessary.

COMMERCIAL PROSPECTS

Much propaganda is being made of the new control methods, and not only sellers of insecticides but everybody interested in the cotton business are contributing to this.

In general the farmers agree that the new methods are technically and economically sound. They are, however, hesitating to adopt them immediately on a large scale—principally dusts—on account of their cost which is much higher than that of the usual spraying with lead arsenate (against leaf worm alone). In spite of this a large number of farmers are preparing to employ new products and methods next season, at least on part of their cotton fields.

If the forthcoming practical applications are successful, if further experiments show the possibility of lowering the concentration or dosages to be used, and if we can compete with other insecticide suppliers, we are sure that within a few years we can develop a large insecticide market for cotton alone.

SEED DRESSINGS

By Dr. R. C. WOODWARD

(*Abridged version*)

DEFINITION

SEED dressings may be "seed disinfectants" or "seed protectants", and these two terms indicate the uses to which they are put. The former destroy pests—largely fungi—on the surface of the seeds. The latter protect the seed from infection by fungi and other micro-organisms during the germinating period when the seed is placed in the soil, or from insects. There is an additional rather special type of seed disinfection which involves the destruction of an organism which has become situated within the seed; but, up to the present, no chemical method has yet been evolved to effect disinfection of such seed satisfactorily without harming the embryo itself. The control of such diseases has been obtained by heat treatment under carefully controlled conditions, as, for instance, the hot water treatment for the control of loose smut of barley.

HISTORICAL

Historically, seed treatment to control disease can be traced back to very early days, but perhaps one of the earlier instances providing some evidence of the value of seed treatment was the accidental discovery of disease-free wheat plants grown from ship-wrecked wheat recovered from the coast of Cornwall. Here seemed to be evidence for the beneficial effect of salt water on wheat seed in controlling surface-borne bunt of wheat. It was in 1882 that Bordeaux mixture, that is copper sulphate and lime, was accidently discovered as a curative or preventive of potato blight and of mildew on vines in France, as is well-known in literature on this subject. This discovery led to the development of the use of copper sulphate for allied purposes, and we find not long after this copper sulphate solution being used successfully on cereal seeds in the control of the seed-borne fungi. This treatment became more and more understood and its capacity to damage better appreciated, as one research worker after the other with painstaking care investigated the problem with the inadequate means at his disposal. After the discovery of the usefulness of copper sulphate as a seed dressing, which incidentally is still being widely used on wheat in many countries, improved treatments not so damaging to the germinative power of wheat and other cereals were discovered. We proceed from the use of formaldehyde in England to the more practical adoption of copper carbonate in Australia, and from there to the discovery in Germany of organo-mercurials in 1920. This latter discovery became the basis for the

wide-scale commercialisation of seed disinfection in agriculture made possible by the very great advantages of the organo-mercurials in respect of (*a*) activity at extremely low concentrations, and (*b*) safety to seed. This type of seed dressing is now well established and widely used in most parts of the world.

THE MODERN SEED DRESSINGS

The mercurial seed dressings have, however, one major disadvantage, that is their hazards to health, particularly during the dressing operation where large seed-treating plants are used and adequate precautions are not taken to avoid continued exposure to the mercury-containing seed dressing powder.

There is a large range of mercurial compounds used in seed dressings. The organo-mercurials are more effective than the inorganic mercurials and there is a gradient in fungicidal efficiency among the organo-mercurials which is related closely to their volatility. The greater the volatility the greater the fungicidal efficiency. But along with greater fungicidal efficiency of the more volatile organo-mercurials goes the greater risk to health.

Among the organo-mercurials used in seed dressings are the following :—

Phenyl Mercury Acetate (PMA)
Ethyl Mercury Chloride (EMC)
Ethyl Mercury Phosphate (EMP)

Of these, the most effective fungicidally and the most dangerous to health, is EMP. The safest to health is PMA and this chemical is among the more fungicidal in the non-volatile class. Although volatility plays a most useful part in the effectiveness of organo-mercurial seed dressings, since the amount necessary for effective disinfection of grain when action at a distance occurs, is small, the danger attending their use has tended more and more to persuade manufacturers to change to less dangerous types and, consequently, to those having a lower volatility. A very great deal of work has been done by Imperial Chemical Industries Limited in the development of efficient organo-mercurial seed dressings with the minimum risk to the user.

In recent years there have been fresh developments in seed dressings avoiding mercurials and relying for fungicidal activity on new organic compounds. But organic compounds not based on mercury are much more specific in their action and, therefore, have a restricted use as opposed to the wide field of use of mercurial seed dressings. Among the chemicals which are being developed in this field is included tetramethylthiuramdisulphide (TMTD), the basis of Plant Protection Ltd.'s 'Nomersan' and of the 50% TMTD product which is likely to replace this on groundnuts and certain other crops.

TMTD is finding specific uses, largely as a seed protectant and its use on groundnut seed and on flax seed has been well developed. In the United Kingdom 'Nomersan' is exclusively used on all flax seed sown. Although extensive trials have been carried out with TMTD seed dressing on cereals, the high efficiency of the organo-mercurials has not been reached by this type of seed dressing, particularly in respect of certain of the well-known seed-borne diseases such as leaf stripes (*Helminthosporium spp.*) and, to a lesser extent, the smuts. It would appear that the more "fleshy" types of seeds such as ground nuts and peas, which are more subject to rotting than cereals, benefit to a greater extent from the seed protectant value of TMTD.

SEED DRESSING FORMULATIONS

It has already been shown that certain organo-mercurials and certain non-mercurial organic compounds are effective in seed disinfection and seed protection. The quantities of such materials required are extremely small. It is therefore necessary that they be well distributed over the surface of the seed to obtain the maximum effect. This can best be done by:—

(*a*) extending the active ingredient with a carefully selected carrier which has been treated to ensure the maximum dispersion and adequate adhesive properties.

(*b*) the use of fluids containing the active ingredient.

To obtain an adequate coverage of seed it is estimated that 0.2% by weight of the seed is the dosage for British formulated seed dressings if thoroughly applied. Where, however, adequate coverage is not required, as in America with the volatile mercurials, lower dressing rates give equally good results. This explains the difference between the American and British recommendations for their respective products; the American product is generally based on a volatile mercurial, and the dosage rate recommended is ½-oz. per bushel, whereas the British product avoids as far as possible the inclusion of any major proportion of the active constituent as a volatile mercurial and the dosage rate for the formulated seed dressing is 2-oz. per bushel.

As for liquid seed dressings, there has been a recent development in Scandinavia using an alcoholic solution of a suitable organo-mercurial. The high concentration of the mercury in such a product makes it, however, dangerous to handle from the container as well as during the dressing process and very strict precautions are required at all stages, including an enclosed seed dressing machine to avoid health hazards to operators. This type of seed dressing is highly effective, but despite all existing precautions it fails to avoid serious risks to users.

Development of seed treating machinery has followed similar conventional lines. Excellent automatic seed dressing machines have been developed in Great Britain, the outstanding among which is the Robinson Seed Dresser. The research required in the development of

this machine was sponsored by Plant Protection Ltd., but the machine itself is manufactured by specialist machinery manufacturers in Great Britain. There are many other types of good seed dressing machinery available in Great Britain, ranging from the hand-operated simple barrel type to the Robinson, and all those interested in developing the seed dressing market should carefully assess the suitability of machines available for their own requirements.

A completely new development has recently come about in the development of seed dressings, and that is the development of insecticidal seed dressings.

SEED DRESSINGS CONTAINING "GAMMEXANE" gamma-BHC AND ORGANO-MERCURIALS

It had never been thought possible to extend the principle of seed disinfection against fungi and micro-organisms to include insecticidal properties. By this is meant, not the protection of stored grain from insect attack, but the protection of seeds and seedlings in the soil from attack by soil-inhabiting insects. This step has now been achieved and has been abundantly proved in extensive field trials where "Gammexane" applied as a simple seed dressing, has been used successfully in the control of wireworm and certain other pests. It will be of interest to trace the history of this development, which in its early stages is to the sole credit of Imperial Chemical Industries Ltd.

During the initial period of development of the uses of "Gammexane", after its discovery by I.C.I., it was tried as a soil insecticide. The first soil insect pest which was investigated and later exhaustively studied was the wireworm (*Elateridae*) and it is of interest and instructive to learn what motivated this work and how the practical problem was approached in Great Britain under the difficult exigencies of war. Wireworm became one of the major problems of economic importance because much pasture land was ploughed and sown to cereals to provide the main staple of our diet, namely bread, during this period. It was essential that as great a proportion as possible of cereal grains be produced in the United Kingdom. As pasture provides ideal ecological conditions for wireworm, freshly ploughed-up grassland usually had very high wireworm populations. A population level of one million per acre had been shown to be potentially dangerous to most farm crops. A new situation, therefore, was presented to the British farmer without means of taking effective action. It was at this time that the newly discovered insecticide—"Gammexane"—was tried as a soil treatment. Field trials were laid out and continued for several seasons in a determined effort to establish the efficacy of this insecticide in the control of wireworm. The first successful results were obtained in applying the insecticide to the prepared soil before sowing. Experiments made it clear that good

practical control of wireworm with adequate protection of plants was obtained by the application of crude BHC as follows :—

(a) 'Agrocide' 2 (0.45% gamma isomer) applied broadcast at 1½-cwts. per acre = 12-ozs. gamma-BHC per acre.

(b) 'Agrocide' 2 (0.45% gamma isomer) applied by combine drill down the rows only at ¾-cwt. per acre = 6-ozs. gamma-BHC per acre.

It was argued from the above results that if the quantity of gamma-BHC per acre when broadcast over the whole of the field amounted to 12-ozs. per acre whilst when combine-drilled down the rows it amounted to 6-ozs. per acre, with approximately equal results, then there was a possibility that an even smaller quantity, discretely distributed, might still give a satisfactory or practical control. Would the placing of gamma-BHC even more closely to the seed than in the drill row and *in still smaller quantities* be effective ?

The practical point at issue was the possibility of using the seed itself as the distributing agent for the ' Gammexane ' insecticide—not hoping so much for beneficial effects from the insecticidal proofing of the seed, of which there was the parallel case with fungicides, as for the protection of the seedling from attack. Results showed that good protectant properties were afforded to both the seed and to the developing seedling by sowing seed dressed with a suitably formulated dry dressing containing ' Gammexane '.

When studying the possibility of ' Gammexane ' seed dressings for wireworm control it was clear that in many cases seed disinfection (for control of fungi, etc.) would also be required. If by one operation the seed could be fungicidally disinfected and dressed with " Gammexane ", then a major advance of great importance would have been gained. Investigations showed that the activity of the organo-mercurials contained in 'Agrosan' GN was not interrupted or at all affected by the inclusion of " Gammexane " gamma-BHC in seed dressings. The fungicidal efficiency of the organo-mercurial component on which so much work had been done, was found to remain unimpaired. A new product based on this information is now being introduced and will shortly be added to the sales range under the name of ' Mergamma '.

Wherever soil inhabiting insects attack seeds or seedlings in intensive or extensive agriculture, it will be of the greatest interest to determine whether or not " Gammexane " gamma-BHC used as a seed dressing contributes an effect in insect control which is economic. This hope is near realisation on a number of insect pests in different countries, whilst in Great Britain wireworm control by such a method has become an accepted fact. The very great prospects of success for the control of soil insects additional to wireworm are now put before those attending this Conference for their consideration and active participation in trials on specific local problems.

THE LEAF-CUTTING ANT IN COLOMBIA

By ADALBERTO FIGUEROA P.

(*Summary in English*)

INTRODUCTION

THE problem of this insect in Colombia, as in other countries where this and related species are found, has posed a most difficult task not only from the technical viewpoint but also from the legal and administrative angles.

Few insects have defied with such vigour attempts to protect agriculture from its attacks. Not only have scientists been called upon to solve this problem but Government officials have been urged on by the general demand of the peasantry to take official action.

VERNACULAR NAME

The species common in Colombia, known scientifically as *Atta cephalotes var. Isthmicola*, is known popularly here as " Hormiga arriera ". This name has been given to it by the peasants to depict the similarity of its mode of locomotion to that of cargo-laden travellers who, in days gone by, used mules, oxen and horses to carry their cargoes through the mountain valleys by narrow and tortuous roads.

In other countries it is known by a variety of names, such as " Bibijagua " in Cuba ; " Bachaco " in Venezuela ; " Sauva Cirtadeira " in Brazil ; " Parasol Ant " in the Caribbean, etc. It should, however, be pointed out here that in these countries the species concerned often differs from ours or is at any rate of different subspecific rank.

BIOLOGICAL ASPECTS

The biology of our species has not been studied in detail. Such a study would call for a special scientific project demanding several years' work and considerable expenditure. General information, however, is available from the observations of entomologists as well as peasant growers.

The genus *Atta* exhibits a special type of social life with a typical " colonial " organization which is either (*a*) reproductory—males

and females of the colony—or (*b*) colonies formed by the sterile female ants which are of various sizes and have a variety of duties. The food of this group of insects was found in Brazil by Mario Autuori to consist of the fungus *Rozites gongylphora.*

In the Valle del Cauca, Colombia, mating and resumption of activity after hibernation occur as the first rains fall at the beginning of the rainy season. Most pronounced activity in the colonies occurs during the rainy season.

This species makes its nest at a mean depth of 1.60 metres (5 feet) in valley regions and at 2—2.3 metres (6 feet 3 inches—7 feet) on mountain slopes. In the latter sites they are more difficult to attack because of the numerous corridors and subterranean passages which cover great distances.

Our recommendations for trials of control methods are largely based on the studies of foreign observers notably by Huber, Goeldi, Eidmann, Ihering, and Mario Autuori at the Instituto Biologico de São Paulo, Brazil. The experiments of T. E. K. Potter in Trinidad and also work in Peru have greatly assisted us in learning a little more about how to deal with this pest.

EXISTING METHODS OF CONTROL

(*a*) *Old Routine Methods.*

(1) Flooding the ants' nests.
(2) Injection of petrol and setting light to the main openings of the nests.
(3) Burning sulphur in portable burners and injecting the gas into the main openings.
(4) Inserting cyanide preparations into the larger openings by means of a spoon.
(5) Protecting trees by tying lengths of fresh banana or plantain leaves round the trunk so as to provide a barrier.

Experience has shown that none of the above methods is really effective.

(*b*) *Methods used by the Government.*

Official methods at present in use by the Secretariat of Agriculture and the Federation of Coffee Growers in their campaign against this pest are based on outside experience with certain local modifications. These official campaigns represent at least 90% of the effective control exercised at present against leaf-cutting ants, since the peasants themselves have little or no initiative. Co-operation between the Government and the peasant is essential, but it has been necessary to introduce certain laws to enforce suitable action. In this respect we have one of the most complete juridical organizations for putting this enforcement into effect.

The Government has adopted the following methods.

(1) Combustion of a 2 : 1 mixture of arsenic and sulphur which is introduced into the mouth of a Buffalo-Squire Blower in the form of 2 oz. pellets. Dosage : Four 2 oz. pellets per medium-sized ants' nest (area visually estimated as 40 square metres). One operator works the machine and the other blocks the apertures to a radius of 20 metres.

(2) Where the necessary machinery is not available Carbon bisulphide is inserted into the main apertures at a rate of half-a-bottle for a medium sized ants' nest and one bottle for large nests. The openings are sealed for a radius of 10—15 metres.

Method (1) has the advantage that when wisely applied at the right time it gives effective control at a price which suits the pocket of even the poorest peasant. The disadvantages of this method are:—

(*a*) It fails if the correct dosages are not applied.
(*b*) The machinery employed is expensive. The blower costs approximately $60.00 (Colombian)
(*c*) The apparatus is cumbersome and heavy to carry.
(*d*) Two men are required to operate it and labour is expensive.
(*e*) Arsenic is a dangerous poison.

Method (2) gives good results when employed sensibly and no ignition is necessary. Furthermore no machinery is needed and only one man need be employed. There are, however, several disadvantages :—

(*a*) It fails in the case of deeply embedded ants' nests in mountainous country.
(*b*) The cost of the method is quite uneconomical for the peasant.
(*c*) Carbon bisulphide is unpleasant and highly inflammable, and therefore a most dangerous substance to use.

BRAZILIAN METHOD OF CONTROL

Until the 'Agrocide' Smoke Generator became available we had advised the Valle del Cauca Government to use carbon bisulphide by the Brazilian method using the J.P. (Pupo) Rod. This method was devised by Mario Autuori and his colleagues at the Instituto Biologico of São Paulo, Brazil.

This system consists of the application of carbon bisulphide through artificial channels made by an iron tube of $\frac{1}{2}$—$\frac{3}{4}$ inch diameter and $5\frac{1}{2}$—7 feet long which is constructed in sections. At the top is a handle and at the lower end a cone. The cone measures $1\frac{1}{2}$ inches long, with the upper diameter $\frac{1}{2}$—$\frac{3}{4}$ inch and the lower diameter $\frac{1}{8}$ inch larger than the diameter of the tube.

When the ants' nest has been located and its area calculated by visual means the operator proceeds to pierce the ground with the J.P. rod, on a square pattern, leaving a distance of two paces between each bore hole. The rod is introduced with vibrating thrusts until a weak zone is encountered indicating that it has reached one of the ant cells. The rod is then extracted and after some minutes it will become obvious if a live cell has been pierced as ants will begin to emerge. If no ants emerge the bore hole made will have penetrated into a refuse or empty cell.

After all the holes have been bored the negative ones sealed and the positive holes temporarily sealed, 10—15 grammes of carbon bisulphide are inserted into each positive hole with a hand blower after which the apertures are sealed again. This method has given excellent results and is now used by the Pest Control Company of the Valle del Cauca. Whilst it has the advantage of being an efficient control method which utilizes lightweight and portable tools there are certain disadvantages such as the expensive and dangerous nature of carbon bisulphide already referred to. Two men are required to operate this method.

PROPOSED EXPERIMENTS IN COLOMBIA

With the assistance of agriculturists attached to the Agricultural Department we have planned a project for testing various new methods of control and comparing them with the existing methods already described. These trials will be conducted on two different types of land, the level country of the valleys and the undulating land of the mountains. The two new methods it is proposed to try out are the 'Agrocide' Smoke Generator and 'Agrocide' 3 Dust and the results of using these will be compared with the Buffalo-Squire method and with the Brazilian method. As a variation we also intend to use 'Agrocide' Smoke Generators in conjunction with the Pupo Rod and we anticipate better results by this means. The efficiency of each method will be determined on a basis of points and each will be carefully costed and observations made on the behaviout of the ants.

The question of costs is a very important one and in this respect the 'Agrocide' Smoke Generator is, at present, at a disadvantage. Whilst 'Agrocide' 3 Powder is cheaper it requires bellows to apply effectively and the treatment has to be repeated frequently. The method most favoured, at the moment, is certainly the 'Agrocide' Smoke Generator, but it is essential that its price should be such as to make its use economic. The Colombian Government is moreover extremely interested in this new method of attack as they consider it is a way in which the peasant can tackle the problem for himself without any official assistance. We realize, however, that to be successful the campaign against the leaf-cutting ant depends on the fullest co-operation of all concerned.

THE CONTROL OF PESTS, DISEASES AND WEEDS OF SUGAR CANE IN THE BRITISH CARIBBEAN

Part of paper entitled "The Sugar Industry of the British Caribbean"

By T. E. K. POTTER

PESTS

THE pests attacking Sugar Cane within the territory, are, with few exceptions limited in their economic importance. There is naturally a variation between the islands, but generally speaking it can be said that there are only two main types which are of constant importance and which are responsible for an appreciable financial annual loss. These are (*a*) Sugar Cane Borers and (2) Sugar Cane Froghopper.

In addition, the following can be of sporadic importance: (3) The Root Borer "Vaquita"; (4) Brown Hardback Beetle; (5) the Yellow Cane Aphis; (6) Fall Army Worm. It is only on occasions that any of these assume economic importance.

(1) Sugar Cane Borers

These include two species of small Moth Borer (*Diatrea Saccharalis* and *D. canella*) and the Giant Moth Borer (*Castnia licoides*).

At one period in the history of the Sugar industry, *Diatrea spp.* constituted a serious threat, as stalk infestations were being recorded as high as 40% for a crop. However, the introduction of egg and larval parasites has served to keep these insect pests under fair control and reduced the infestation to under 5% during normal seasons. The most effective parasites are: *Metagonistylum* (The Amazon Fly), *Trichogramma minutum L*, and *Lixophaga diatrea* (Cuban Fly).

The Giant Moth Borer—*Castnia licoides*—is by no means as serious as the *Diatrea spp.*, but there are years when its incidence is more marked than others. The only control measure practised is hand collection.

No attempt has yet been made to control either of these Borers by chemical means.

The incidence of *Diatrea spp.* is general throughout the territory, whereas *Castnia* is more localized.

(2) Sugar Cane Froghopper

The Sugar Cane Froghopper can be classed as the pest of greatest economic importance to the industry, although it is only to be found in Trinidad and, to perhaps a lesser extent, in British Guiana.

The Trinidad Froghopper—*Tomaspis saccharina Dist.*—is estimated to cause 10% reduction in the annual Trinidad crop, or an annual loss of 100,000 tons of Cane valued at approximately £125,000 ($600,000.00 U.S.). The British Guiana species—*Tomaspis flavilatera*,—has only within recent years been credited with economic importance but it is most probable that it will become of increasing importance in the future.

It is considered that a pest of such importance in one sugar growing territory—albeit a small one—might be of interest and as a consequence more detailed information is given of its history and the measures directed towards its control.

Tomaspis saccharina is a member of the Homoptera Order, family Cercopidæ and is indigenous to Trinidad. There are other members of its genus which attack Sugar Cane and Graminaceous crops, but it is unlikely with anywhere near the same degree of intensity.

The Froghopper adult is about 7.5 mm. long with basically dark-coloured wings and yellow markings. The gravid female oviposits an average of 50 eggs in her lifetime, site of oviposition being in the soil and/or trash in and around the cane stool within a radius of 10" (25 cms.) of the stools' centre. Under conditions obtaining in Trinidad the Froghopper season commences after 4 months (January to May) of what is termed the 'Dry Season,' during which time the average monthly precipitation is 2" (51 mms.). The commencement of the Froghopper Season follows 3 weeks after the opening of the 'Rainy Season,' and both continue to December, during which the average monthly rainfall is in the region of 8" (203 mms.) During the Froghopper Season, there are three or four separate 'broods' or adult emergences, the first commencing in May/June, and the last in November/December. Entomological investigation has determined that the Froghopper adult females of the second and subsequent broods in any one season, are capable of ovipositing two types of egg,—one which will hatch within a period of 8/12 days and the second which has the ability to aestivate, under suitable conditions for hatching. It has been shown that it is the accumulated total of aestivating or 'long period' eggs, oviposited by 2nd and subsequent brood females, during the period July/December in one year, which give rise to the first brood in May/June of the following year. Further, that 1st brood adult females lay eggs which only give rise to 2nd brood adults, and do not lay any 'long period' eggs.

Upon emergence from the egg, the nymph goes through 4 moults within a period of 21/25 days, during which time it remains near to the site of oviposition and feeds upon the cane rootlets near to, or on, the surface, or in cracks, of the soil. Also, immediately upon hatching, the nymph surrounds itself with a spittle mass, consisting of aerated liquid, which serves both as a physical protection as well as a humidor. The nymphs emerge as adults in the morning most usually, when they crawl up the stems of the cane and into the leaf funnel at the top, where all adults remain during the daylight hours as they are photophobic.

At dusk the adults fly on to the blades of the cane leaves and commence sucking the sap therefrom. Infestations of more than 30 nymphs and 40 adults per stool for a period of one week, are sufficient to cause ' blighting ' of the cane. The ' blighting ' effect on the cane is a result of the dying, and consequent drying-out, of the tissues of the leaf, caused by the sap removed and possibly also by the injection with the Froghopper saliva of some compound toxic to the cane. A field of cane which has had a heavy infestation over a long period, has the appearance of having been burned ; such a field can have its yield reduced from an estimated 40 tons per acre—to 5 tons per acre.

As can be imagined, a pest of such importance received early attention, and as far back as 1912, recommendations to aid its control were investigated. These included the encouragement of Toads and Lizards in the fields to attack the nymphs, and the protection of birds which fed on the adults.

Later, it was determined that the larva of the Syrphid Fly fed on the nymphs and exercised a certain degree of natural control, and that two Fungi, the *Green Muscardine* and *Empusa* were parasitic on the adults. These latter, to this day, are a very effective means of natural control, but unfortunately, conditions for their widespread dissemination and effectiveness are very specialized and occur too sporadically to be dependable. This was demonstrated when the fungi were artificially bred and their spores distributed throughout infested fields. No increased parasitism was noted due to this release, over that which occurred naturally.

The era of chemical control opened late in 1920 when it was observed that nymphal spittle masses could be destroyed by the application of " Cyanogas " Dust (Calcium Cyanide Dust). However, the use of such a poison was dangerous, and further it was determined that the powder only killed the nymphs with which it made direct contact. Consequently it was necessary to clean the stools and surrounding soil of trash before application, and in areas seriously affected four or five applications would be necessary before control was affected. It therefore became a very expensive operation, in addition to being dangerous.

Various attempts were then made on egg destruction, and it was discovered that the egg could not withstand dessication. Consequently, if an infested field were ploughed, there would be no Froghopper incidence within it during the following plant cane crop. However, it was obviously uneconomic to plough under a 1st ratoon crop to secure control, and this suggestion had little or no practical significance.

In 1940, a serious attempt was made to control the adults by applying an activated Pyrethrum dust to them at night-time, through the ' drift-dusting ' technique. Due to the high cost of Pyrethrum, it was found to be uneconomic to apply a powder of sufficiently high Pyrethrin content to kill the adults, and the strength of the powder used was only strong enough to paralyse the insects temporarily. However, from these experiments, the technique of ' drift-dusting ' for dust application on Sugar Cane was proven to be practical, and it is still being used today.

In 1944/46, the technique of ' drift-dusting ' the adults was recommenced, but the insecticide used was a 5% DDT Dust applied at the rate of 50-lbs. per acre. On occasion, Sabadilla Dust was incorporated with DDT, but the addition did not appear to be justified. It was demonstrated that DDT was able to produce a high mortality on adults, but in order to control ' blighting ' it was essential that the timing of the dust application be correct. In other words, the insecticide had to be applied when adult emergence was approaching its peak, as if this was not done it would be necessary to make several applications on the same brood.

To ensure correct timing of dust application, a rather elaborate system of nymphal and adult population assessment for each infested field is necessary. This entails daily counting of nymphs per stool, at the rate of 10 stools per field, and also daily counting of adults per stem of cane, at the rate of 40 stems per field (The average size of a field in Trinidad is 10 acres—4 hectares).

The stools counted are in 3 separate traverses running across the field, in each traverse 13, 13 and 14 stems respectively being counted. The stools for nymphal counts are selected at random as near as possible to the traverses.

The population counts are then recorded graphically, and from the graph it is a simple matter to determine the correct date to apply the insecticide.

Whereas this method of control was employed on one estate of 3,000 acres its success is completely dependent on the integrity of the observers and the staff employed in the control procedure. It was determined that on many occasions one field had to be dusted on as many as 15 different occasions, which is not satisfactory from every point of view, especially as the operation has to be performed at night time. It was claimed that the DDT was having a residual effect on the adults for as long as 15 days after application, but this was subsequently disproved.

In 1946, benzene hexachloride was first tried on a field scale against the adult Froghopper. The formulation used was 'Agrocide' 3 containing 0.65% gamma BHC applied at the rate of 30 lbs. per acre. The 'drift-dusting' technique was used, the dust being applied from the windward trace by means of a Messenger "C" Power Duster, operated from an 80 h.p. "Caterpillar" Tractor through the power take-off.

The population assessment method as previously described was used for timing the operation, and excellent results were obtained. However, it was established that the limit of control for the insecticide was 100 metres from the dusting trace on level land; the presence of undulating land complicated the method considerably; and it was emphasized that a competent, reliable Froghopper staff was essential for economic success.

In 1947, DDT and 'Agrocide' 3 large-scale trials were instituted and although 'blight' incidence was considerably reduced on all treated areas, and consequently an enormous quantity of cane was saved, it was determined that the average Cane Estate organization was unable to deal with the problem adequately.

In 1947 also, a small trial was made to determine the effect of a pre-hatching application of benzene hexachloride to the soil in and around the cane stools. The site for the experiment was determined by sampling the soil around the stools for eggs. The benzene hexachloride formulations used were 'Agrocide' 2 Dust (0.45%gamma BHC) and Liquid 'Agrocide' 3. The insecticides were applied one month before nymphs appeared, and the 'Agrocide' 2 treatments at rates of 4 and 8 cwts. per acre provided adequate protection for at least three months.

In 1948 trials were laid down on 4 estates to determine the effect of applications of 'Agrocide' Powder formulations to the nymphs. On one of these estates, of 450 acres, from indications obtained in 1947, this method was adopted on a field scale. The 'Agrocide' formulation used was a mixture of 'Agrocide' 7 (2.6% gamma BHC) & locally produced Ground Limestone (Calcium carbonate) of 100-mesh fineness, finalising in a product of 0.5% gamma BHC. The results of these trials have shown that an application of 1-cwt. per acre (121 kilos per hectare) of this formulation, applied by a Root Rotary Hand Duster to the base of stools infested with nymphs, produced a nymphal mortality approaching 100%, and further that this complete control has lasted for a period of 4 months. A similar application made with 5% DDT powder on nymphs produced a mortality of only 30—40% and was not as satisfactory as the 'Agrocide' formulation.

The value of such a method of control lies not only in the fact that one application would appear to give complete control for the froghopper season, but also, in a territory where roughly 50% of the total cane area is cultivated by peasants, the method of application does not entail large capital outlay for equipment, as any ordinary hand duster will suffice for treating small areas.

In July, 1948, one large Sugar Company hired a Bell Aircraft Company's Helicopter for dust applications to the adults. On account of the fact that adult control by whatever means, is closely tied in with correct timing application, and also that dust application has to be made from dusk onwards, the Helicopter was subject to the same limitations as the 'drift-dusting' technique by Messenger Duster. Results of the Helicopter application method demonstrated that a more even dust distribution was possible for all areas—both level and undulating—but the cost of the application was considerably higher. Consequently, in spite of the glamour attributed to the method, helicopter dusting was unsuccessful.

Trials on the use of more recently evolved insecticides and ovicides —such as D.N.O.C., E.605, Chlordane and Chlorinated Camphene— purely as ovicides will be made in 1949, but up to the present date it can be stated that the only satisfactory, economic and practical method of control is by a treatment of the nymphs with 'Agrocide' Powder of 0.5% gamma BHC.

(3) The Root Borer—"Vaquita". The larvae of the weevil, *Diaprepes abbreviatus* have at times presented a problem to sugar cultivation. Control is rather ineffectively attempted by a parasite—*Tetrastichus haitiensis*—toads and hand collection.

(4) The Brown Hardback Beetle. The larvae of this beetle—*Lachnosterna smithi*—cause damage by boring into the base of the stems. Control measures attempted include destruction by the predator—*Pyrophorus luminorus*—hand collection and cultural methods. Experiments in the use of benzene hexachloride against this pest are to be instituted in Barbados this year.

(5) The yellow cane aphid—*Sipha flava*, can, on occasions be a serious pest in certain territories when natural control by predators and entomogenous fungi fail. It is presumed that application of an 'Agrocide' formulation, by means of hand dusters, would be a satisfactory means of control, if the infestation warranted treatment. No trials have been made of this method.

(6) Fall Army Worm & Caterpillars. The two more important leaf-eating caterpillars of the territory are—*Laphygma frugiperda* and *Remigia repanda*. Localized outbreaks of these have been controlled by dusting with Lead Arsenate powder.

DISEASES

Sugar Cane in the territory is remarkably free from disease, the most important being the virus Mosaic. This is kept under control by rogueing and the cultivation of resistant varieties. Root diseases such as Root Rot (*Marasmius*) and Gumming Disease (*Xanthomonas vascularum*) are present, but proper cultural methods and selection of resistant varieties appear to effect complete control.

WEEDS

Weed control is an item of great expense in the Caribbean. The operation is almost completely performed by hand labour, and in a few cases by mule-drawn cultivators and also by rotary hoes.

In the islands of lower rainfall, where weed control is part of the soil-water availability problem, the use of the selective hormone weedkillers 'Agroxone' ('Methoxone') and 2, 4-D ('Chloroxone') has met with a certain degree of success. The weeds on which this method of control has been successful at a rate of 4-lbs. active ingredient per acre in spray form are Nut-grass—*Cyperus rotundus* and water or pond grass—*Commelina sp.*

Where rainfall is heavier, the main weeds of economic importance are themselves grasses, but trials with these chemicals as a pre-emergence application have produced results which indicate that they may be successfully used under such conditions.

Trials are also being made with them incorporated with activated oils and pentachlorophenate, but no results are as yet available.

ACKNOWLEDGMENT

The use of DDT in Froghopper nymph control is taken from a private communication from Mr. F. Blackburn, Research Officer, Caroni Ltd., Trinidad.

RECENT PROGRESS IN LOCUST CONTROL

By O. B. LEAN

We have omitted from this article the introductory section of Mr. Lean's paper. In this he discussed the fundamental biological facts relating to the behaviour of locusts and grasshoppers which are fully dealt with by Mr. Lean in his article "The Locust Problem"—Part I, appearing in this journal (Vol. 1, No. 1).

DURING recent years much has happened in the locust world. We have experienced major plagues and we have averted others. On my travels I have seen operations in many countries and I should like to give examples of what has been done in face of attacks similar to those you have recently experienced in South America.

As most of my travels start from London, let us begin there. Housed in the Natural History Museum is the Anti-Locust Research Centre, under the Directorship of Dr. Uvarov. This is the official headquarters of British effort and has become the unofficial headquarters of anti-locust work throughout the world. One of the functions of this centre is to record and analyse all reports of locust activity and the value of this part of its work was well illustrated in 1942 when the Centre told the British Government that the Desert Locust was escaping from its outbreak areas and that for several years to come hungry swarms must be expected to roam throughout the Middle East and Northern Africa. To reduce the risk of loss of crops, which would have been extremely serious at that critical stage of the war, the British Government established the Middle East Anti-Locust Unit to assist and encourage control in areas where the home government were not expected to undertake sufficiently drastic measures.

Let me describe something of what this Unit attempted. We go first to Saudi Arabia, chosen as the main scene of operating because it was an important spring breeding ground and because the local government was powerless to organise control. Here in Uruguay, you know that each annual invasion of your country comes approximately at the same season and the swarms arrive from the same direction. This is true for all locust species. Their migrations are not haphazard and swarms move around with the climate and seasons, remaining always under congenial conditions. From their analysis of all available data, the Anti-Locust Research Centre has learnt much

about the movements of the Desert Locust. Once the swarms have escaped from the outbreak areas and the plague is in full swing, the migrations follow the same pattern each year. The swarms follow the rains. During the summer rains they can breed along a belt across Africa, south of the Sahara, and in India. As these regions dry up the swarms migrate to where rain falls in winter and spring ; those from India move into Persia and Arabia ; those from Central Africa fly into Arabia and into Northern Africa. Later there is a return migration.

Beginning in a small way in 1942, the Middle East Anti-Locust Unit gradually built up an impressive organisation in Arabia and has continued its work there during six seasons. With its headquarters in Buraiman Camp, not far from Mecca, the Unit conducted its campaigns over vast areas of inhospitable desert. The essence of the organisation was to place small mobile parties at strategic centres to clean up the areas one by one. Each had its own base camp which could be moved at will ; each had its own motor transport for local use, but it drew supplies of food and locust stores from headquarters and the convoys which took these out had, in some instances, to travel each trip 1,500 miles across roadless and often trackless desert. To give some idea of the magnitude of this transport problem the trucks of the Unit in one season covered 2½ million miles. Life was not always pleasant, always hard, and sometimes drinking water had to be collected from a hundred miles away. Wireless communication proved invaluable. Each party had its transmitter and talked daily to headquarters where every movement of parties and locust swarms was recorded on a large map.

Only by keeping in such close touch with the ever changing situation could the man in charge direct his forces to secure optimum results.

The drivers learnt to take their lorries across almost impossible country but there was some terrain where no motor transport could move. Then we used camels, of special value for long surveys, and British officers travelled for weeks on end, living as nomadic Arabs, collecting information on swarm movements and breeding.

Throughout we laid great stress on maintaining friendly relations with the local people ; so much depended upon their co-operation. The work of our Doctor smoothed the way. For instance, one youth had never seen a European before, neither had his family, and they ran for miles across the desert at sight of our convoy. When we caught them up, explained our purpose and treated their sick, our difficulties ended. After Arabia, let us take a glimpse of Persia, where another section of our Unit worked for three years. The locust problem was similar, the approach rather different. Persia had an active Agricultural Department but by mutual agreement it was desirable to strengthen the local Anti-Locust Section. During those war years we established in Persia the most striking example of the International co-operation that is absolutely essential when fighting a pest which carries no passport and requires no visas to cross from one country to the next. Here in Persia, Persians, British, Russians, Indians, and Iraqis strove

together against the common enemy in complete harmony, each contributing his share to the varied requirements of the campaign. The type of the campaign was similar to that in Arabia and transport difficulties just as great.

In Arabia all locust reports were collected at camp headquarters; in Persia they were sent to Teheran. In our regional office in Cairo we collated all this data and similar information from our units in Abyssinia, the Yemen and elsewhere. Everything went to London for Dr. Uvarov to view the broad picture and in return he sent us a monthly summary and map of the current situation. Such means encouraged essential team work and helped workers in the field to see their local campaigns as a part of a wide operation and for us all to forget artificial state frontiers.

From organisation I pass on to the killing of the locust. Until recently the digging up of egg fields was far too popular. Much labour was wasted and results were invariably unsatisfactory.

Another and more spectacular method which I, and most locust entomologists, have also tried to discourage is the flame thrower, only too popular, I regret to say, in South America. Spectacular though it is, great numbers of locusts escape. The method is costly and far slower than standard poison baiting.

In all anti-locust campaigns in Africa and the Middle East we have relied upon poison baiting as the standard mode of attack; other methods have their uses certainly but I think all are agreed that poison baiting still remains the most effective and most economical.

Bait can be mixed in small quantities as required by the field gangs. Generally it is better to prepare bait in bulk at central mixing stations. At the bait factory at Asmara in Eritrea bait is mixed all the year round so that ample supplies can be distributed to field centres long before the rush of the actual campaign, when the strain on transport is always heavy. After drying in the sun the bait is either bagged, or, sometimes taken loose to field depots.

I wish to emphasise that baiting itself is not quite so straightforward as it may appear and very often reputed failure is not due to the bait at all but to the manner in which it is applied. It would take far too long to describe correct baiting technique and I will only stress one point. Nobody can apply bait successfully unless he understands the behaviour of locust hoppers. These insects go through a daily programme of resting, feeding and marching, all according to temperature, and it is quite useless scattering bait when nothing but a change in temperature will make them feed.

Bait can be distributed in several ways. Probably the commonest method is by hand. It is perhaps slow but it is economical as bait is applied only where required. Such field gangs are kept supplied by small lorries; sometimes, as back in Eritrea, by camels.

In reasonable country, when dealing with large hopper bands, the work can be accelerated by simply throwing bait from a slow-moving lorry, though this sometimes leads to the bait being spread far too thickly. An obvious refinement is the mechanical bait spreader. I believe machines of this type have a great future and might be adopted in most locust-ridden countries. Travelling at 5 m.p.h. it spreads bait evenly over a strip 30 feet wide and will cover one acre in three minutes. It requires only two men to operate; one to drive the truck, one to feed the distributor.

Not long ago most poison bait was made up with arsenical insecticides and we all know that they were never popular around the farm or in grazing land. The fear of poison bait ended with the introduction of the new locust poison, benzene hexachloride, sold as 'Agrocide' 7.

The efficiency of poison baiting against hoppers is normally appreciated—with correct application the kill should approach 100% —it is perhaps less known that bait is highly effective against adult locusts.

May I give one final word of advice on bait. Use it as soon as possible when the hoppers are young and very dense.

I wish now to deal briefly with the use of aircraft. There is nothing novel in the idea but great strides in technique have been made and these may change the whole conception of anti-locust policy. Much has been written about aircraft giving perhaps too great confidence in their possibilities.

Russia has used aircraft during many years for the routine treatment of the outbreak areas of the migratory locust. Sometimes they apply bait, more often arsenical dusts to poison the reeds upon which the locust feed. We, in England, began serious experiments in 1943, starting with arsenical dusts on the model of the Russian technique. The trials were carried out in Persia and though kills were good we were far from satisfied as regards cost and general applicability. From arsenic we changed to dinitro-ortho-cresol, and from Persia we transferred to Kenya. Kills improved but results varied as it was proved that, whilst under moist conditions, the DNOC killed, it was almost harmless during the dry heat of the day. Furthermore, locusts are disturbed by an approaching low flying plane and many move out of the way of the dust cloud. To spread dust on the ground the plane must fly low.

The next development was to spray liquid DNOC from planes flying 200 or 300 feet above the ground. Liquid DNOC was far more toxic than dust and it killed equally well under all atmospheric conditions. The high flying plane did not disturb the locusts. Many difficulties had to be overcome and finally the results of two years' intensive research were put to the test in autumn 1947 in Central Africa in the swamps around Lake Rukwa. As a privileged guest I

watched painstaking laboratory results and abstruse mathematical calculations dramatically confirmed. In one operation a mortality of 98% was obtained at a dosage of half-gallon per acre. In another, nearly two square miles were 95% cleared of locusts, using a very slightly higher dosage; using six aircraft, one after the other, the ground was treated at an average speed of 12 acres per minute. To obtain such results, I must emphasise that very strict scientific control of the aircraft, their course, height and the rate of discharging insecticide with continuous recording of winds is vital. The aircraft must be guided by ground parties who demarcate the area to be treated, usually with smoke markers, and who direct the whole operation, communicating with the pilot either by a prearranged system of signals, or preferably with radio. Perhaps if the locusts are to be destroyed on the ground it may be best to attack them from the ground. The new aircraft technique was designed for the attack of swarms in flight and for this purpose there seems no alternative. It is never easy to place a dust cloud, and to dust a flying swarm it may be necessary to fly through the swarm—a hazardous and unpleasant experience. The spray with its large drops can be placed with certainty even when flying at some considerable height above the target.

In Africa, British scientists have preferred to use DNOC. In South Africa and in Australia concentrated solutions of 'Agrocide' have been favoured.

I believe these techniques have a great future and they may be of special value in a country like Uruguay, where hungry swarms cross the frontier to cause immediate damage in a rich agricultural belt. One can visualise air operations along the western frontier killing off each swarm as it arrives to prevent not only the damage to your crops but the expensive anti-hopper campaign that must be undertaken if the locusts are allowed to breed.

Finally, one word about policy and what we, over in the Old World, believe should be the next move in the war against locusts.

We began by purely defensive measures in agricultural areas designed to keep locusts from the crops. Later we changed from pure defence to attack and chased the locust wherever it could be reached. We fought against it in the deserts of Arabia and in southern Persia; in South America it is being attacked in its winter quarters. All such measures are necessary when once the locust comes out of the outbreak areas. To avoid these wholesale campaigns it was decided some years ago that attention should be directed towards the outbreak areas. Once they had been demarcated we intended to keep them under permanent supervision and whenever the locusts began to multiply they should be destroyed. This method of suppression has been, in fact, tried and it has succeeded. The whole southern half of Africa was saved from a crippling plague of the Red Locust by intensive operations in the outbreak areas, and, as I have already described, an outbreak of the African Migratory Locust was checked.

Sound as is this policy of suppression, it implies resolute and continuous action in the outbreak areas, where conditions are typically far from pleasant, and it means recurrent expenditure. To better suppression we now think of absolute prevention. This means that whilst we still look towards the outbreak areas we shall not wait for the locust to swarm before we attack ; instead, we aim at so modifying these areas that swarm formation is no longer possible. It is indeed a long-term policy and we can hardly guess how the necessary changes in vegetation may be brought about. We do believe that continued research into the habits of the locust and its relationships with its environment may show the way.

When I surveyed the outbreak area of the Migratory Locust, I found the habitat of the solitary phase to be great open grassland plains. When I returned to the Middle Niger, fourteen years later, flooding from the River Niger had been controlled in some regions. Instead of open grassland stood quite dense scrub and I knew that no locust could live there. Other outbreak areas may be modified in similar ways, by raising or lowering the water table, by controlled grazing, and so on.

The human race, threatened by world famine, can ill afford to feed the locust. Let us look forward to, and strive for, the time when the clouds shall disappear and the farmer shall wake to find his green and very pleasant land free from the ancient scourge, our old enemy the locust.

BANANA LEAF SPOT
(*Mycosphaerella musicola.* Leach)
THE DISEASE & ITS CONTROL

By R. V. TIPLER

WHEN I was asked if I would prepare a note on Banana Leaf Spot for presentation at your Conference, it was with considerable trepidation that I accepted. To prepare, in a country afar, a paper to be read in a region where first hand knowledge of the disease is commonplace, and from which has emanated much brilliant research for the benefit of the whole banana-producing community, seemed an ambitious and unenviable project.

I can, however, plead as a qualification for attempting the task, my association in England with the researches which led to the development of 'Perenox' and which lay behind its introduction to the West Indies at the time when I.C.I. was co-operating with the Jamaican authorities in their leaf spot control programme.

I can recall well the high-pressure work, in laboratory and in glasshouse and garden, carried out on specially grown banana plants, and in which we were involved in our endeavour to meet the requirements for a material which should be effective, tenacious and visible on bananas.

Within the short space of time at my disposal, it is impossible to deal fully with the problem, and I shall therefore confine my attention to a presentation of the salient features of the disease, the habits of the fungus responsible and conditions affecting severity of disease, with a view to indicating the reasons for the control measures now advocated. It is my hope that this paper will form a basis for subsequent mutual discussion of the problem in the light of conditions prevailing in the banana-producing region which you represent.

THE DISEASE : A DESCRIPTION

The disease is due to the microfungus *Mycosphaerella musicola* Leach, the name given to the "perfect" ascospore stage, which Leach discovered, of the fungus once known in its conidial stage as *Cercospora musae* Zimm.

Once the fungus has infected a banana leaf, it develops therein, producing lesions on which three kinds of spores are found, all of very different significance in the spread of the disease. With one type of spore, those produced in "spermagonia" we shall not deal here, as they do not directly affect the course of disease. Of the other two

types, we will deal first with the

—*conidia.* These spores are produced on the upper surface of leaf spots in masses termed "sporodochia." They are liberated in the presence of moisture on the leaf surface, and are minute bodies which may be likened in their functions to seed. Conidia are dispersed from the sporodochia and reach uninfected leaf surfaces in rain or dew water, where under favourable conditions they germinate. The resulting growth penetrates the stomata or breathing pores of the leaf, usually on the undersurface. The leaf is now infected *internally* where the fungus develops at the expense of the leaf tissue.

The course of the disease varies with the severity of infection and the proximity of spots. These may coalesce in lines or patches, giving areas of necrosis, or the spots may cut off areas of leaves which die and produce the symptom known as "scorching."

It is on or in the leaf spots when the central area is darkening or after it has turned grey, that the various spore-bearing bodies are produced, from which spores are liberated to repeat the cycle on newly-unfolding leaves.

The total period of development from spore to spore takes an average of about 35 to 40 days, but variations from about 10 to 100 days are known.

Leach has shown that conidial infection occurs mainly on the undersurface of the heart leaf on the areas of the relatively unwaxed marginal region which are successively exposed as the leaf unfurls. This results in "line-spotting," in which the spots appear in lines parallel to the left margin (that is, the only margin exposed during most of the unfurling period) and to some extent diagonally across the base of the right-half of the leaf.

The conidial infection as described is by far the most common and is responsible for most of the disease and its spread, but a second type of spore

—*ascospores*—is produced under certain conditions. These are capable of initiating a different sort of infection. The ascospores, when mature, are shot out from "perithecia" embedded in the leaf spots, mainly in the early morning, and are carried upward in light air currents, lodging on the undersurface of opened foliage. Leach has shown that ascospores are caught principally towards the tips of leaves and are thus responsible for "tip-spotting," a type of infection which starts at the leaf tip and spreads down the leaf more or less evenly on each side of the midrib.

This differentiation between conidial "line-spotting" and ascosporal "tip-spotting" is of great importance, as the type of spotting present indicates the source of infection and has a bearing on control programmes.

Secondary infection of older leaves by conidia and ascospores does occur, but as the occurrence is infrequent, we shall not deal with it here.

THE DISEASE—EFFECT ON THE PLANT

Strange to say, banana leaf spot does not appear to retard foliage development, but it does reduce the reserves of the plant by lessening the effective leaf surface and, when disease is severe, by causing premature leaf fall and death. The most serious effect is loss of crop, which is not only manifested in reduced bunch and finger size, but in the more insidious effect on maturation. Fruit from diseased plants may be buff-coloured instead of normal white, and may ripen prematurely on the tree. If disease is less severe, the green harvested fruit may become soft and yellowish before shipment, or even ripen prematurely in refrigerated ship transport, so that the consignment arrives in an over-ripe or unsaleable condition. Moreover, flavour and aroma may be adversely affected.

THE DISEASE : FACTORS AFFECTING CONTROL MEASURES

Although much work, a lot of it empirical in nature, has been carried out on control measures, it is thanks to Leach's work that a fuller knowledge of the factors influencing development and spread of disease has been obtained. He has put in order many hitherto disconnected observations, and provided a sound and rational basis for control.

His work, it is true, refers particularly to Jamaican conditions, but his findings are so wide and cover so many factors that a careful perusal of his work in relation to other local conditions will surely indicate the best method of control to adopt—and the pitfalls to be avoided !

It may be of interest to know that Leach's work is being applied, with every evidence of success, to leaf spot control in so distant a country as the Belgian Congo.

The factors influencing control measures are many, and as it will be necessary to simplify and summarise them for the sake of brevity I make no apologies for omissions. I would, however, re-emphasise that Jamaican conditions are especially in mind when dates are mentioned.

1. Conidial production depends mainly on the presence of moisture on the sporodochia, usually in the form of dew, not of heavy rain. After intensive spore production the sporodochia appear to need a rest before further production occurs. Spore production is therefore most intensive after a dry non-sporing period.

2. Conidial production may occur at any time, but factors affecting it are heavy dews, particularly after dryish periods, and night temperatures. If dewing and temperatures are low, due to shading or the period of the year, conidial production, conidial viability and proportion of successful infections is decreased. In Jamaica the danger period for conidial infection is from March to October, though local differences occur.

3. Conidia infect mainly the margins of unfurling heart leaves, and secondary infection of older leaves is normally of little importance. It follows that unfurled heart-leaves may be internally infected even though no symptoms are evident, and spraying at this stage to *prevent infection* is useless. As from infection to appearance of spotting takes at least three weeks, and heavy spotting is not apparent until the fifth to eighth week, spraying as a control measure will not have any apparent effect until the heart-leaf at the time of spraying is eight weeks older, *i.e.*, when it is the fourth or fifth youngest leaf.

4. Sprays may influence conidial-type infection in several ways :—

(*a*) Spray deposit present on leaf spots may prevent or reduce spore-production. Bordeaux Mixture and 'Perenox' are both effective, but the former more so.

(*b*) Spray deposit may render the dew, in which it slowly dissolves, toxic to the conidia, so that they cannot germinate and bring about infection.

Thus conidia produced on a leaf on which is spray residue may be transferred to a new leaf in dew which is already toxic. They may also be transferred in dew to a sprayed leaf, the deposit on which renders the dew toxic to the spores. In neither case will infection occur. Bordeaux Mixture and 'Perenox' are both effective, but in this case 'Perenox' is the more powerful inhibitor of germination.

5. Ascospore infection normally occurs only on the youngest leaves. Sprays will not suppress ascospore formation in, or liberation from, the perithecia, as these are embedded in the leaf spots. As ascospores are forcibly ejected in the *dry* state from the perithecia, spray residues on the leaf of origin will not affect their germination. Sprays will only prevent ascospore infection if a toxic residue is already present on the surface on which the spore alights. Ascospore infection is therefore the more difficult to control, particularly as the under-surfaces of top leaves require protection.

6. Ascospore production, resulting in " tip-spotting," normally occurs in Jamaica during the winter, August to January, and being more difficult to control it is the aim of spraying to so reduce " line-spotting " during the summer that by August the leaves bear a minimum of spots in which ascospores can be produced. This results in reduced " tip-spotting," and control of conidial infection is made easier for the following spring. In this way the general infection level is reduced over a season or two.

7. Certain soil conditions exist which are responsible for out-of-season ascospore formation. Under these conditions ascospores may be produced at any time of the year except late winter, and control is rendered much more difficult. Leach gives details of contributory conditions in Jamaica, but it is sufficient to state here that they are all associated with inadequate soil aeration, poor and shallow tilths, and variability in the oxidation-reduction relationship in the soil.

As out-of-season ascospore formation may result in poor control with a normal spray programme, an investigation of soil condition in relation to ascospore formation may be advised when spraying does not prove a success.

CONTROL OF THE DISEASE

1. Spraying

Spraying with copper fungicides, notably Bordeaux Mixture, has been advocated from the earliest days, and has been used with varying degrees of success. Copper lime dusts have also been used, generally with less success. The spraying programme which used to be advised consisted of repeated application of 1% Bordeaux Mixture (0.25% copper) at three-weekly intervals commencing before the rainy periods and continuing at intervals thereafter as practicable. This proved a formidable programme, involved spraying in the rains and as it was not based on a thorough understanding of the disease was at the most of only moderate value. The aim was to keep the foliage protected *after it had unrolled*, and Leach's work has demonstrated that at this stage conidial infection has occurred and spraying to prevent it is useless.

Bearing the seven points enumerated in the previous section in mind, we will now summarise Leach's recommendations for a rationalised spray programme :—

(*a*) Spraying should commence with the period of active plant development in spring, when conidial production and infection are on the up grade, but *before* fresh spotting manifests itself.

(*b*). Application should be continued at least at three-weekly intervals, to ensure that heart-leaves are sprayed and that a good cover is obtained on all upper surfaces of leaves.

(*c*). If leaf-spotting is light, or has already been brought partially under control, "three-leaf" spraying, in which the heart-leaf and undersurfaces of the next three youngest leaves are sprayed, can be carried out at three-weekly intervals.

(*d*). Spraying should continue until early October, when night temperatures fall and conidial infection decreases. Preventive sprays are, however, recommended at about four-weekly intervals until January, when spraying can be discontinued till spring (March).

(*e*). If severe leaf spotting develops in late summer to autumn, due to unsatisfactory control of disease early in the year, weekly "heart-leaf" spraying will be necessary to prevent its infection by ascospores. Although it is difficult and expensive to apply this treatment in large plantations or on tall, older plants, it is the only effective way of controlling such an attack. Spraying will be necessary usually throughout the ascospore season (August to January).

(*f*). Where out-of-season ascospore formation occurs, control is more difficult, and the intensification of the spray programme to maintain adequate winter control of the disease may prove uneconomic.

The actual programme to be adopted will depend upon conditions of climate, soil and disease prevailing in the territory concerned and must be worked out locally.

2. Spray materials

1% Bordeaux Mixture (4 lb. copper sulphate crystals plus 4 lb. hydrated lime per 40 gallons of water, *i.e.* 0.25% Cu) and ¼% 'Perenox' (1 lb. per 40 gallons of water, *i.e.* 0.125% Cu) are both very effective sprays for use in a control programme. In some circumstances the efficiency of 'Perenox' has been increased by the addition of 0.1% 'Alboleum' as sticker or 0.1% Liquid 'Agral' as wetter. This is particularly the case, with Bordeaux Mixture also, when "heart-leaf" spraying is carried out. Unfortunately a satisfactory "wetter-sticker" has not yet been formulated.

Considerable work was carried out in an attempt to improve, by formulation, the visibility and tenacity of 'Perenox.' The former is difficult of achievement, because cuprous oxide itself has high pigmentation value and the addition of reasonable quantities of opaque diluents cannot possibly have sufficient effect. Moreover, visibility must necessarily be lower than that of Bordeaux Mixture due to the lesser amount of total solids in the spray—1 lb. as compared with 8 lb. per 40 gallons.

Tenacity was not materially improved by any of numerous materials tested, although one formulation, manufacture of which could not be continued, showed some promise. You may, however, be encouraged to learn that with the possible development of a higher-copper 'Perenox' attention is again being focussed on the necessity for obtaining a formulation more suitable for use in the tropics and on hard-to-wet foliage.

3. Application of Sprays

Success of a spray programme may depend quite as much on the methods by which the sprays are applied as upon the timing of the sprays and the choice of the spray material. Spraying should be carried out with adequate supervision, thoroughly and conscientiously, under conditions conducive to maximum spray retention. Spray nozzles should be far enough from the leaves to allow the spray to deposit on the foliage, but not so far as to make coverage of all, including the top and heart leaves, unsatisfactory. An endeavour should be made to avoid run-off, as spraying to excess wastes material and reduces spray retention. Thus power sprayers developing fine mists are more satisfactory than low-pressure equipment giving coarse droplets. Incorporation of wetter or sticker may be advisable especially for heart-leaf spraying.

Attention is being devoted to the improvement of spray retention by development of new equipment which will produce very fine mists which will settle on and cover foliage without coalescing and running-off. Such sprayers will use less liquid per acre, a very important factor in some areas. I.C.I. and Plant Protection Ltd. are in the forefront of this work, and though many difficulties must be solved, the principle of the 'Agro' sprayer now used successfully on ground crops in temperate countries is being adapted for use under the conditions associated with banana plantations.

4. Crop Hygiene

As spores will continue to be produced on dead leaves and trash, and, as Leach has shown, ascospore production cannot be prevented by spraying, removal of all such material is a matter of elementary but essential hygiene. This measure in itself will not eliminate the disease, but it is an effective way of reducing potential infective material. Trash removal and disposal should in general commence before the onset of the ascospore season (early August in Jamaica) and of winter rains, and should continue for three or four months. Where soil conditions are responsible for out-of-season ascospore infection, trash disposal should also be carried out in the drier early spring to prevent build-up of summer tip-spotting.

5. Shading

By preventing heating of foliage in the day, and slowing down the cooling rate at night, shading tends to reduce dew formation on the leaves. This effect is more noticable where dewing is not naturally heavy. As upper leaves shade lower ones so that dew formation is not so heavy on them, conidial production by upper leaves is usually the more important source of infection.

Leach is therefore of the opinion that, contrary to accepted practice, light shading should be considered as a possible means of controlling leaf spot in areas where only moderate dewfall is normal.

6. Varieties

Research and experience have shown that all the well-known commercial varieties, Gros Michel, Dwarf Cavendish, Congo and Giant Governor are very susceptible as plantation crops. Wardlaw and Cheesman at the Imperial College of Tropical Agriculture have studied varietal susceptibility and the breeding of resistant or immune varieties on the basis of the natural resistance of a number of wild species of *Musa*. Some success has been attained, but a truly acceptable commercial resistant variety is still awaited. The incorporation of desirable commercial characteristics with resistance to Leaf Spot and, of equal importance, with resistance to Panama disease, is a task of considerable difficulty.

PROBLEMS IN FORMULATING PLANT PROTECTION PRODUCTS

By W. R. ORRELL

THE normal process by which a new insecticide or fungicide comes into being, and reaches you as a series of products, takes place in several distinct steps.

(1). The synthesis of a number of different substances which may or may not have the right type of biological activity. This is the job of the research chemist.

(2). Biological testing, both for their action against pests and for the possible danger to the plants themselves. This is mainly the job of the laboratory biologist.

(3). Testing on a field scale under as many different climatic conditions as possible, is mainly the job of the field biologist.

(4). The formulation of a series of products from the preferred material. These products must be in such a form that they may be stored safely, used readily according to a simple set of directions, and, of course, be as economical as is consistent with efficiency. This is the main job of the formulation chemist, who must work in such a way that he can produce a process to hand to the Works, so that there can be no possibilities of mistakes when they come to manufacture in large quantities. Further, the formulation chemist has to supervise the making of the first few batches so as to advise the works on how to overcome the teething troubles which invariably arise when a new product is manufactured.

Of course, the formulation chemist is also involved in steps two and three above, that is, in preparing samples and small batches for laboratory and field evaluation, but it is the fourth step which is his main field and his sole responsibility.

You will see from this that, although primarily, the formulation man must be a chemist, he has to know enough botany, entomology and mycology to discuss problems with the biologist and enough chemical engineering to deal with the Works Engineer. In addition, he must have enough commercial sense not to formulate grossly uneconomic products, and must be able to deal with field difficulties once the product is on the sales range.

Whilst new ways of applying pest control products are being developed—smokes, aerosols and so on—there are still two major

ways of applying insecticides and fungicides—as liquid sprays and as dusts. In other words, as nearly all pest control chemicals are far too concentrated to use undiluted, the formulation chemist has to devise means of putting them up in such a way that they can readily mix with water or be extended by cheap but effective inert dusts.

A. LIQUID SPRAYS

It is one of the trying characteristics of most chemicals which are of any use for pest control purposes, that they won't dissolve in water. (The only exceptions I can recall at the moment are lime sulphur fungicide, nicotine and hexaethyltetraphosphate insecticides and 'Methoxone' weedkiller; even these present other formulation difficulties which sometimes almost outweigh their easy solubility).

So far as we know of about three ways of overcoming the proverbial difficulty of making oil (with which I include any insoluble chemicals) and water mix—the production of emulsions, dispersible liquids and dispersible solids.

EMULSIONS

Many ponderous volumes have been written about emulsions, and they tell us which end of the molecule goes into the oil and which into the water, how much energy is required to break up a cubic centimetre of oil into droplets one micron in diameter, and so on. But not one of them gives any clue as to how to prepare a stable emulsion from a given oil or other chemical. So we are driven back to collecting our own data.

Now an emulsion consists of an insoluble liquid which we will call the oil or oil phase, finely dispersed in the form of droplets throughout a water phase, and for our purposes the emulsion must remain stable for years. Nature gives us a clue in that wonderful product—milk—where butter fat is emulsified, poorly from our point of view, and the emulsion is stabilised by the emulsifying agent, casein. For many years casein has been used in insecticide products as an emulsifying agent, but it is gradually being replaced by synthetic preparations. We at Yalding are fortunate in having access to and full information about a whole series of emulsifying and surface active agents produced by I.C.I. Duestuffs Division for use in the textile industry. These fall into three categories: (1) anionic products such as sulphonated alcohols, (2) cationic products which are usually organic quaternary ammonium salts, and (3) those which are not ionic at all, but consist of alcohols or phenols condensed with ethylene oxide. This latter type interests us particularly, and perhaps its use in overcoming difficulties connected with one product will illustrate a new trend in formulation work.

We, in England, have a fairly large demand for a dinitro ortho cresol (D.N.O.C.)/petroleum wash for use as a winter wash to control aphid, red spider, capsid and psylla on deciduous fruit trees. At first sight the problem of producing a good product from these active ingredients does not seem formidable. D.N.O.C. is sufficiently soluble in petroleum oil and an alkaline caseinate is a good emulsifier for this

type of oil. A product made up on these lines appeared quite satisfactory, but there were difficulties. D.N.O.C. is a fairly strong acid and it reacted with the alkaline emulsifier and was removed from the oil phase into the water phase as sodium and ammonium salts. Now the salts of D.N.O.C. are not very soluble in water and they came out of solution in the form of fine crystals; so that eventually the spray consisted of oil containing a very, very little D.N.O.C., water containing a little D.N.O.C., and fine crystals of the sodium and ammonium salts of D.N.O.C. All this was proved by centrifuging the product and examining analytically the layers so produced. Worse than this, the chemical changes I have mentioned also affected the emulsion and it changed its characteristics, becoming thick and difficult to mix with water. The substitution of one of the non-ionic wetting agents for the alkaline caseinate got over all these difficulties. The D.N.O.C. remained in the oil phase and the product remained stable for years. This stability is so marked that difficulties have actually arisen in analysing the product by ordinary laboratory methods which failed to " split the emulsion" !

A further difficulty met with in this product illustrates another function of the formulation chemist. D.N.O.C. as I said before, is a fairly strong acid and attacks metals. In the alkaline type of formulation most of the free D.N.O.C. was in the water phase and metal drums for the product could be protected by giving their inside surface a coating of oil. In the newer formulation all the D.N.O.C. is in the oil phase already, so an oil coating on the drum gives no protection. Research was therefore necessary to overcome this difficulty either by adding a suitable inhibitor or by lacquering the drums.

You will realise that in an emulsion the oil phase is already distributed as droplets in the water phase and when you dilute it with water for spraying you simply extend the emulsion by increasing the volume of the water phase. In its essentials the diluted emulsion is the same as the concentrated emulsion with the sole exception that the water phase is bigger.

DISPERSIBLE LIQUIDS

There is another method of making an insoluble material miscible with water. This involves the production of a " miscible oil." Most of you will be familiar with pharmaceutical tinctures in which the active material is dissolved in alcohol giving a clear solution. When this solution is added to water a milky emulsion results. In the case of the pharmaceutical product the emulsion need not be very stable because it is made up in small quantities and consumed immediately after dilution. In the case of the pest control product, where the dilution is made up in large quantities and may have to remain in a spray tank for several hours, the emulsion has to remain stable. At least three components are therefore required in a good dispersible liquid—the active ingredient, a solvent for the active ingredient, and a stabilising agent for the emulsion which is formed when the dilution is made up. After

many trials we have reduced our preferred stabilising agents to three or four chosen from a range of surface active agents made by I.C.I. Dyestuffs Division. The choice of solvent is, however, more difficult, as those having the right properties—*i.e.* solvent for the active ingredient and the dispersing agent, and a high flash point—are usually expensive, and this type of formulation is generally limited to speciality products where expense is not of prime importance or to products where the active ingredient is itself expensive and used at a very low concentration.

We have succeeded in making very good preparations of this type from D.D.T., benzene hexachloride and E.605. In the latter case particularly, this method shows great promise.

One particular difficulty with this type of product may be mentioned. Where the active ingredient is crystalline it often happens that a very good dilution is first formed on adding the product to water. Later, however, the very small crystals, which form the non-aqueous phase of the emulsion, begin to grow and rapid settling out of the active ingredient results. This is due to the fact that the " aqueous phase " really consists of a dilute solution of solvent. This acts as a bridge between the small crystals suspended in the dilution and small quantities of the active ingredient are picked up from the solution by some of the crystals. A corresponding amount of active ingredient is dissolved from others. Consequently some of the crystals grow at the expense of others and finally a very coarse, rapidly settling suspension results.

This difficulty can be overcome by including a " protective colloid " in the formulation, if one can be found which is sufficiently soluble in the solvent.

DISPERSIBLE POWDERS

Another way of making insoluble products mix with water is to make them into dispersible powders. This introduces a fresh set of difficulties and problems.

Theoretically if one grinds a powder fine enough it should, on stirring with water form a suspension whose stability will depend solely on the size and weight of the individual particles. The smaller and lighter the particles the slower will they settle down. Unfortunately there are difficulties here, too.

First of all most solids, and in particular organic solids, don't wet very easily when added to water. They float on the top and refuse to mix readily when you attempt to dilute them.

Secondly, even when you have, by one means or another, managed to wet them the particles themselves stick together and form aggregates whose size and weight are, of course, far greater than the ultimate particles of the product.

There are fortunately certain surface active agents which have the property of making powders wet out easily, and there are others which cause the aggregates to break up into their ultimate particles.

Some organic products which have a low melting point cause trouble when they are being ground, because the heat generated by the grinding process melts them in the grinding plant with possible disastrous results both to the product and the mill. Before a good wettable and dispersible powder can be prepared all these points have to be considered—as well as many others—and each of them has to be made the subject of a separate investigation. When each individual problem has been solved the results are combined and, with luck, a good dispersible powder is produced.

B. DUSTS

Turning now to the question of the formulation of dusts, a different set of problems arise.

The first fact that one has to determine is the concentration of active ingredient required to do the job for which the product is intended. This information must be supplied in precise terms by the biologist.

Next we have to consider the crop or types of crop on which the product is intended to be used. It is, for instance, no use recommending a heavy dust for use on large fruit trees, though a heavy one may be ideal for use on cabbages or other crops grown low on the ground.

The same remarks apply to the particle size of a dust. A very fine particle size is indicated for use on high trees, a less finely ground material may be better for use on ground crops.

These factors are covered by examining likely inert fillers for " packing density " (that is the weight of the dust which will just fill a 100 c.c. cylinder), and for particle size or particle size distribution. This latter determination has been the subject of much investigation and there are many ingenious pieces of apparatus developed by physical chemists which allow the formulation man to judge a particular dust. (In spite of their frequent use in specifications, sieve fractionation figures usually give very little idea of the true nature of a dust from the point of view of particle size because most of the dusts we use have very large percentages passing the finest sieves made.)

Another feature of dusts to which we have to give particular attention is what some call their internal cohesion but which we prefer to call stickiness. There is a tendency in all dusts for their particles to stick to one another. We have noticed the same feature in dispersible powders —the characteristic which caused the powders to aggregate in water and necessitated our having to add a dispersing agent.

This tendency to internal cohesion is present in all powders and the force with which it acts is constant for a given powder. It varies enormously, however, from powder to powder, and it has several practical effects. Two of these may be mentioned now. A powder with a high degree of internal stickiness does not dust well and, in addition, it tends to stick to the internal surfaces of spraying machinery.

In tests we have carried out with particular powders, we have actually succeeded in one hour in blocking up the 3 inch ducts of a large dusting machine simply by operating the machine in the normal way, using a dust of particularly high internal cohesion. After cleaning out the machine and substituting a dust of low internal cohesion no deposit at all could be found in the ducts after a full day's run.

I cannot in this short paper deal with all the properties of dusts which interest us, but I think I have said enough to indicate that we do make a very thorough study of the physical properties of our dust carriers before we approve them for use.

* * *

In all our formulation work we have to keep in mind the chemical, as well as the physical properties of the products with which we are dealing. In particular we have to see that the alkalinity or acidity of the added materials do not affect the active ingredients. So pH control becomes a very important factor in our work.

When the formulation work on any product is completed, a Works process is written up and is accompanied by a series of specifications for all the raw materials used and for the finished product itself. Rigid control, under these specifications, is then maintained by the Analytical Section.

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